

WHAT IS CLAIMED IS:

1. A fuel reforming apparatus for reforming a raw fuel containing a hydrocarbon-containing compound so as to produce a hydrogen-rich fuel gas for use in a fuel cell, comprising:

a reformer including a reforming catalyst, the reformer reforming the raw fuel by utilizing at least a steam reforming reaction and a partial oxidation reaction;

a raw fuel supply device that supplies the reformer with the raw fuel;

a water supply device that supplies the reformer with water so that at least a part of the supplied water is used for the steam reforming reaction;

an oxygen supply device that supplies the reformer with oxygen so that at least a part of the supplied oxygen is used for the partial oxidation reaction of the raw fuel at the reforming catalyst; and

a controller that controls the raw fuel supply device, the water supply device and the oxygen supply device,

wherein the controller executes a carbon removal process for removing carbon deposited on the reforming catalyst under a predetermined condition, by controlling at least one of an amount of the raw fuel supplied to the reformer and an amount of the oxygen supplied to the reformer so that an O/C ratio of the number of oxygen atoms O supplied from the oxygen supply device to the number of carbon atoms contained in the raw fuel supplied from the raw fuel supply device becomes larger than an appropriate range of the O/C ratio that is to be established during a normal operation of the reformer.

2. A fuel reforming apparatus according to claim 1, wherein the controller calculates an amount of carbon accumulated in the reformer, based on a history of an operating condition of the reformer, and executes the carbon removal process when

the amount of the accumulated carbon exceeds a predetermined threshold value.

3. A fuel reforming apparatus according to claim 2, wherein the controller selects one of a plurality of carbon removal modes that are prepared in advance, depending upon the amount of the accumulated carbon, and wherein the carbon removal process is carried out in the selected carbon removal mode.

4. A fuel reforming apparatus according to claim 1, wherein the controller calculates an amount of carbon accumulated in the reformer, based on a history of an operating condition of the reformer, and controls the amount of the raw fuel supplied and the amount of the oxygen supplied during the carbon removal process, depending upon the amount of carbon accumulated in the reformer.

5. A fuel reforming apparatus according to claim 4, wherein the controller varies at least one parameter depending upon the amount of carbon accumulated in the reformer, the at least one parameter including at least one of the amount of the raw fuel supplied during the carbon removal process, the amount of the oxygen supplied during the carbon removal process, a length of a period for which the carbon removal process continues, and the number of execution of the carbon removal process.

6. A fuel reforming apparatus according to claim 1, wherein the controller executes the carbon removal process when a required output value of the fuel cell is equal to or smaller than a predetermined value.

7. A fuel reforming apparatus according to claim 1, wherein the controller executes the carbon removal process upon a start of the fuel reforming apparatus.

8. A fuel reforming apparatus according to claim 7, wherein upon the start of the fuel reforming apparatus the controller controls the oxygen supply device and the raw fuel supply device during the carbon removal process so as to supply the reformer with the oxygen and the raw fuel.

9. A fuel reforming apparatus according to claim 8, wherein upon the start of the fuel reforming apparatus the controller controls the oxygen supply device during the carbon removal process so that the amount of the oxygen supplied to the reformer is larger than an amount thereof that is sufficient to permit complete combustion of the raw fuel supplied to the reformer.

10. A fuel reforming apparatus according to claim 8, further comprising:
an electric heater disposed upstream of the reforming catalyst such that the electric heater is operable to heat the raw fuel and the oxygen,

wherein the controller causes the electric heater to heat the oxygen and the raw fuel when the carbon removal process is executed upon the start of the fuel reforming apparatus.

11. A fuel reforming apparatus according to claim 1, further comprising:
a temperature sensor that detects a temperature of the reforming catalyst,
wherein the controller controls the amount of the raw fuel, the amount of the oxygen and an amount of water that are supplied to the reformer during the carbon removal process so as to prevent the temperature of the reforming catalyst detected by the temperature sensor from exceeding a predetermined limit value.

12. A fuel reforming apparatus according to claim 11, wherein the controller executes the carbon removal process by controlling the amount of the oxygen supplied

to the reformer to be larger than a predetermined amount thereof that is set for the normal operation of the reformer.

13. A fuel reforming apparatus according to claim 11, wherein the controller executes the carbon removal process by controlling the amount of the raw fuel supplied to the reformer to be smaller than a predetermined amount thereof that is set for the normal operation of the reformer.

14. A fuel reforming apparatus according to claim 1, wherein the controller executes the carbon removal process by controlling the amount of the oxygen supplied to the reformer to be larger than a predetermined amount thereof that is set for the normal operation of the reformer.

15. A fuel reforming apparatus according to claim 1, wherein the controller executes the carbon removal process by controlling the amount of the raw fuel supplied to the reformer to be smaller than a predetermined amount thereof that is set for the normal operation of the reformer.

16. A fuel reforming apparatus according to claim 1, wherein the controller intermittently executes the carbon removal process a plurality of times.

17. A fuel reforming apparatus according to claim 16, wherein the controller calculates an amount of carbon accumulated in the reformer, based on a history of an operating condition of the reformer, and executes the carbon removal process when the amount of the accumulated carbon exceeds a predetermined threshold value.

18. A fuel reforming apparatus according to claim 16, wherein the controller

calculates an amount of carbon accumulated in the reformer, based on a history of an operating condition of the reformer, and controls the amount of the raw fuel supplied and the amount of the oxygen supplied during the carbon removal process, depending upon the amount of carbon accumulated in the reformer.

19. A fuel reforming apparatus according to claim 18, wherein the controller varies at least one parameter depending upon the amount of carbon accumulated in the reformer, the at least one parameter including the amount of the raw fuel supplied during the carbon removal process, the amount of the oxygen supplied during the carbon removal process, a length of a period for which the carbon removal process continues, and the number of execution of the carbon removal process.

20. A fuel reforming apparatus according to claim 16, wherein the controller executes the carbon removal process when a required output value of the fuel cell is equal to or smaller than a predetermined value.

21. A fuel reforming apparatus according to claim 16, wherein the controller executes the carbon removal process upon a start of the fuel reforming apparatus.

22. A fuel reforming apparatus according to claim 16, further comprising:
a temperature sensor that detects a temperature of the reforming catalyst,
wherein the controller controls the amount of the raw fuel, the amount of the oxygen and an amount of water that are supplied to the reformer during the carbon removal process so as to prevent the temperature of the reforming catalyst detected by the temperature sensor from exceeding a predetermined limit value.

23. A fuel reforming apparatus according to claim 16, wherein the controller

executes the carbon removal process by controlling the amount of the oxygen supplied to the reformer to be larger than a predetermined amount thereof that is set for the normal operation of the reformer.

24. A fuel reforming apparatus according to claim 16, wherein the controller executes the carbon removal process by controlling the amount of the raw fuel supplied to the reformer to be smaller than a predetermined amount thereof that is set for the normal operation of the reformer.

25. A moving object, comprising:

a fuel cell;

a secondary battery;

a fuel reforming apparatus that reforms a raw fuel containing a hydrocarbon-containing compound so as to produce a hydrogen-rich fuel gas for use in the fuel cell;

a driving motor that generates a force to drive the moving object;

a drive circuit that drives the driving motor by using an electric power supplied from at least one of the fuel cell and the secondary battery; and

a controller that controls the fuel reforming apparatus, the driving motor and the drive circuit,

wherein the fuel reforming apparatus comprises:

(a) a reformer including a reforming catalyst, the reformer reforming the raw fuel by utilizing at least a steam reforming reaction and a partial oxidation reaction;

(b) a raw fuel supply device that supplies the reformer with the raw fuel;

(c) a water supply device that supplies the reformer with water so that at least a part of the supplied water is used for the steam reforming reaction; and

(d) an oxygen supply device that supplies the reformer with oxygen so that at least a part of the supplied oxygen is used for the partial oxidation reaction of the raw

fuel at the reforming catalyst, and

wherein the controller executes a carbon removal process for removing carbon deposited on the reforming catalyst under a predetermined condition, by controlling at least one of an amount of the raw fuel supplied to the reformer and an amount of the oxygen supplied to the reformer so that an O/C ratio of the number of oxygen atoms O supplied from the oxygen supply device to the number of carbon atoms contained in the raw fuel supplied from the raw fuel supply device becomes larger than an appropriate range of the O/C ratio that is to be established during a normal operation of the reformer.

26. A moving object according to claim 25, wherein the controller executes the carbon removal process when a required value of the electric power supplied to the driving motor is equal to or smaller than a predetermined value.

27. A moving object according to claim 26, wherein the controller executes the carbon removal process when the moving object is in at least one operating condition selected from a startup condition in which the moving object is started, an idling condition, a decelerating condition, and a key-off condition in which the moving object is stopped.

28. A moving object according to claim 25, wherein the controller controls the drive circuit during the carbon removal process so that an output power of the secondary battery compensates for a reduction in an output power of the fuel cell due to the carbon removal process.

29. A method of controlling a reformer that reforms a raw fuel containing a hydrocarbon-containing compound so as to produce a hydrogen-rich fuel gas for use in

a fuel cell, comprising the step of:

executing a carbon removal process for removing carbon deposited on the reforming catalyst under a predetermined condition, by controlling at least one of an amount of the raw fuel supplied to the reformer and an amount of the oxygen supplied to the reformer so that an O/C ratio of the number of oxygen atoms O supplied to the reformer to the number of carbon atoms contained in the raw fuel becomes larger than an appropriate range of the O/C ratio that is to be established during a normal operation of the reformer.

30. A method according to claim 29, wherein the carbon removal process is intermittently executed a plurality of times.

31. A method according to claim 29, wherein an amount of carbon accumulated in the reformer is calculated based on a history of an operating condition of the reformer, and the carbon removal process is executed when the amount of the accumulated carbon exceeds a predetermined threshold value.

32. A method according to claim 29, wherein an amount of carbon accumulated in the reformer is calculated based on a history of an operating condition of the reformer, and the amount of the raw fuel supplied and the amount of the oxygen supplied during the carbon removal process are controlled depending upon the amount of carbon accumulated in the reformer.

33. A method according to claim 29, wherein the carbon removal process is executed when a required output value of the fuel cell is equal to or smaller than a predetermined value.

34. A method according to claim 29, wherein the carbon removal process is executed upon a start of the fuel reforming apparatus.

35. A method according to claim 29, wherein the amount of the raw fuel, the amount of the oxygen and an amount of water that are supplied to the reformer are controlled during the carbon removal process so that a temperature of a reforming catalyst incorporated in the reformer does not exceed a predetermined limit value.

36. A method according to claim 29, wherein the carbon removal process is executed by controlling the amount of the oxygen supplied to the reformer to be larger than a predetermined amount thereof that is set for the normal operation of the reformer.

37. A method according to claim 29, wherein the carbon removal process is executed by controlling the amount of the raw fuel supplied to the reformer to be smaller than a predetermined amount thereof that is set for the normal operation of the reformer.